

## *1. Introduction*

Between fruits reach their maturity on the tree and they arrive to the consumer hand, they are exposed to several handling procedures (harvesting, transport, packing) where they might become damaged (Kampp, J. and Pedersen, J, 1990). This causes an effective reduction of the quality of the product, and, subsequently, of its commercial value.

Several studies have been carried out to study fruit packing lines (Miller et al., 1991; García et al. 1994) as well as how do impacts really occur on a line using Instrumented Spheres (Zapp et al., 1989). It is of capital importance not only to detect where each impact occurs, but also to identify the kind of impact (Zapp et al. 1990; Bollen, 1993). Therefore it is advisable to use graphic means, as video and photo cameras (Bollen et al, 1990) in order to get as much information as possible about every impact. Finally, the bruise susceptibility of each product must be related with the data registered by the IS. Predicting the probability of bruising (Bollen et al. 1991) and assessing impact damage thresholds of the products (Schulte-Pason et al., 1990; Pang et al., 1991; Schulte et al., 1992) are the final objectives of these studies. Instrumented Spheres are also used to detect impact incidence in harvest operations (Barreiro, 1994) and other postharvest operations as transportation (Schulte and Pason et al., 1990).

The current research has two main objectives. The first objective consists of the evaluation of the potential harming effect of some packing lines from some cooperatives in the region of Murcia with the aid of Instrumented Spheres IS-100. The second one looks forward studying the influence of one packing lines on different stone fruit varieties under the point of view of mechanical damage.

The current study has been developed under the frame of a two-year PETRI Project (Project about Transference of Research Results to the Industry) whose final objectives are to measure the damage susceptibility of citrus and stone fruits exposed to different treatments and to evaluate the quality of harvest and post-harvest operations, studying each of them individually in some cooperatives in the region of Murcia. The final objective of the project is to improve those operations, performing the necessary changes and applying proper treatments, in order to optimize the final quality of the produce.

The results presented in this paper are first-year preliminary results. Only some results of the first-year test have been analysed and included in this paper.

## *2. Materials and Methods*

Two instrumented spheres IS 100 were used to evaluate the quality of handling, grading and packing operations. These devices were developed by the USDA-ARS/Michigan State University Agricultural Engineering research team. Two different-size units were used: an orange-like one with 300.6 g weight and 8.8 cm diameter and a mandarine- or peach-like one weighing 114.7 g and with a diameter of 6.2 cm; both devices equipped with a triaxial accelerometer, a clock, a battery and a memory. Each impact data is reported as acceleration of gravity units ( $g$ 's), where  $1g = 9.8 \text{ m/s}^2$  (Zapp et al., 1989). The impact duration, in *ms*, is also registered. Gathering these two parameters it is possible to create other useful variables (Brown et al. 1990).

Results obtained from measurements made with both IS (8.8 cm Ø and 6.2 cm Ø) show significant differences. Therefore a calibration test was made with both spheres, in order to check if both elements do really measure the same values under identical impact

conditions, as it is supposed to happen. Drops from seven different heights and onto four different-hardness materials were made.

Eight packing lines belonging to six different cooperatives of the region of Murcia were tested, but only two for stone fruit, in Cieza, and two for citrus, in Librilla are included in the paper.

Each grading line test was repeated 6 times at least, to have representative and reliable data of every line.

Video and photographs were also taken to have further information to identify the impact surface characteristics as well as to know how each impact did exactly occur.

The speed of the elements integrating each line were also measured with the aid of a digital tachometer Ono Sokki HT-5200.

Each packing line test was performed as follows: a.) Observation of the handling and packing line. Sketch drawing of the line. b.) Timing of the sphere crossing over the different elements along the grading line. c.) Data collection: Put the IS at the beginning of the line and let it run through it with other fruits. Note transfer times with an external clock. d.) Data analysis: Identification of the high magnitude impacts, the element or transfer point where they take place and the kind of impacting surface.

To study the incidence of a certain packing line on different products an interaction fruit-packing line test was performed. It was only applied to stone fruit varieties due to the difficulty of citrus damages to be observed. For the observation of them immediately after they appear, a dark room and UV lamps are required.

The interaction between the stone fruit grading line 1 and one apricot variety (Búlida) and three peach varieties (Springcrest, Caterina, and Baby Gold) was studied.

Following UNE 34-117-81, ISO 874 Standard, (Fresh fruit and vegetables. Sampling), two equal-size samples of a recently harvested variety (one-two hours) were established, both belonging to the same shipment. The first sample was conformed as the fruit reached the packinghouse; this first one was used as control, nothing was done with it. The second sample was established with fruit that had been put at the beginning of the packing line and subjected to the whole grading-handling-packing process. After that, two equal-size samples, one of the not mechanically handled and one of them mechanically handled, were available.

Every fruit of both samples was observed individually, paying attention to mechanical damages. Surface and longitudinal damages were contabilized. The number and kind of damage of every fruit were noted.

Both samples were kept for 48 hours at room temperature ( $\approx 20^{\circ}\text{C}$ ) and then observed once more. The development of bruises which wer apparent two days before and the presence of new ones, not apperent before, was observed.

Damages were classified as shown in Table 1.

Damage categories	Type of damage	
	Surface	Longitudinal
a	b.s. $< 0.5 \text{ cm}^2$	l.d. $< 1 \text{ cm}$
b	$0.5 \leq \text{b.s.} < 1 \text{ cm}^2$	$1 \leq \text{l.d.} < 2 \text{ cm}$
c	b.s. $\geq 1 \text{ cm}^2$	l.d. $\geq 2 \text{ cm}$
b.s.: bruise surface		
l.d.: longitudinal damage		

Table 1: Damage classes. Dimensions of bruises

To simplify the management of the information derived of this test, damage categories were redistributed, creating two new variables based on UE Standards belonging to Extra/Class I or out of these categories: If a fruit does not present any damage or shows one 'a'-surface and/or one 'a'-longitudinal damage, it belongs to the "exportable category". If it reports more than one damage of any of the categories shown in Table 1, the fruit would not belong to Extra- or Class I UE category, and therefore it would be "non-exportable category". The results of these tests will be presented in these terms.

### 3. Results

#### 3.1. Calibration between 8.8cm Ø-IS 100 and 6.2cm Ø-IS 100.

Both IS measure the same values of the same variables for soft materials, but not for hard surfaces. They must have been calibrated for soft materials and not for hard ones. The 6.2 cm Ø IS, for identical impact characteristics, registers higher 'acceleration peak' values than the big one (fig. 1). This could be due to the different dimensions of both devices, what oblies them to move in a different way through the line. Considering that the small one is more similar to the tested fruits in terms of dimensions, and subsequently movement through the line, than the orange-like one, in these previous results we will pay more attention to the results registered by the small sphere. In any case, results of both IS are refered in this paper.

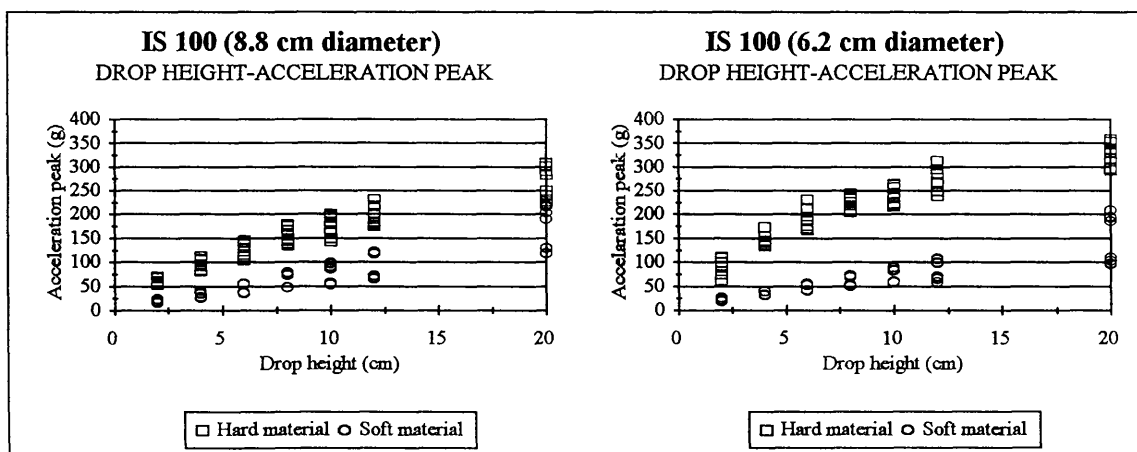


Fig 1. Comparison between big and small IS 100. For same impact conditions, the 6.2 cm Ø IS registers similar acceleration peak values for soft materials as the 8.8 cm Ø IS, but higher values of the same variable for hard surfaces.

#### 3.2. Comparison between four packing lines

IS values obtained in transfers belonging to the tested lines lay well above 50 g's in most of them. Barreiro reported that an impact of 50 g's means a 50 mm<sup>2</sup> for stone fruit (Barreiro, 1995), being this section value the maximum allowable damage surface by EC standards for Class I of this product (fig. 2). Although there is a high variability for the data registered in each tranfer (six runs were made per line), the average impact values are most of them above this risk threshold.

Table 2 shows the highest and lowest probability of a 50 g's or higher impact for transfers in a line, as well as the proportion of transfers of each line which do fit with these highest and lowest probabilities. The probability of a 50 g's or higher impact of

each transfer was calculated as number of runs with an impact equal or over 50 g's / total number of runs.

As seen in fig. 2 and with the information of Table 2 we conclude that citrus lines are generallyly worse designed and/or regulated than stone fruit lines. Much higher impact intensities are registered in these lines than in the stone fruit lines.

Grading lines	8.8cm Ø-IS 100				6.2cm Ø-IS 100			
	L	%T(L)	H	%T(H)	L	%T(L)	H	%T(H)
Stone fruit grading line 1	0.167	37.5	1	25	0	12.5	1	50
Stone fruit grading line 2	0	22.2	1	22.2	0	11.1	1	44.4
Citrus fruit grading line 1	0	7.1	1	35.7	0.167	7.1	1	78.6
Citrus fruit grading line 2	0	13.3	1	53.3	0	6.7	1	46.7

L: Lowest probability of a 50 g's or higher impact of any transfer.

%T(L): Proportion of transfers with L probability

H: Highest probability of a 50 g's or higher impact of any transfer.

%T(H): Proportion of transfers with H probability

Table 2. Highest and lowest probabilities of 50 g's or higher impacts of transfers of a line.

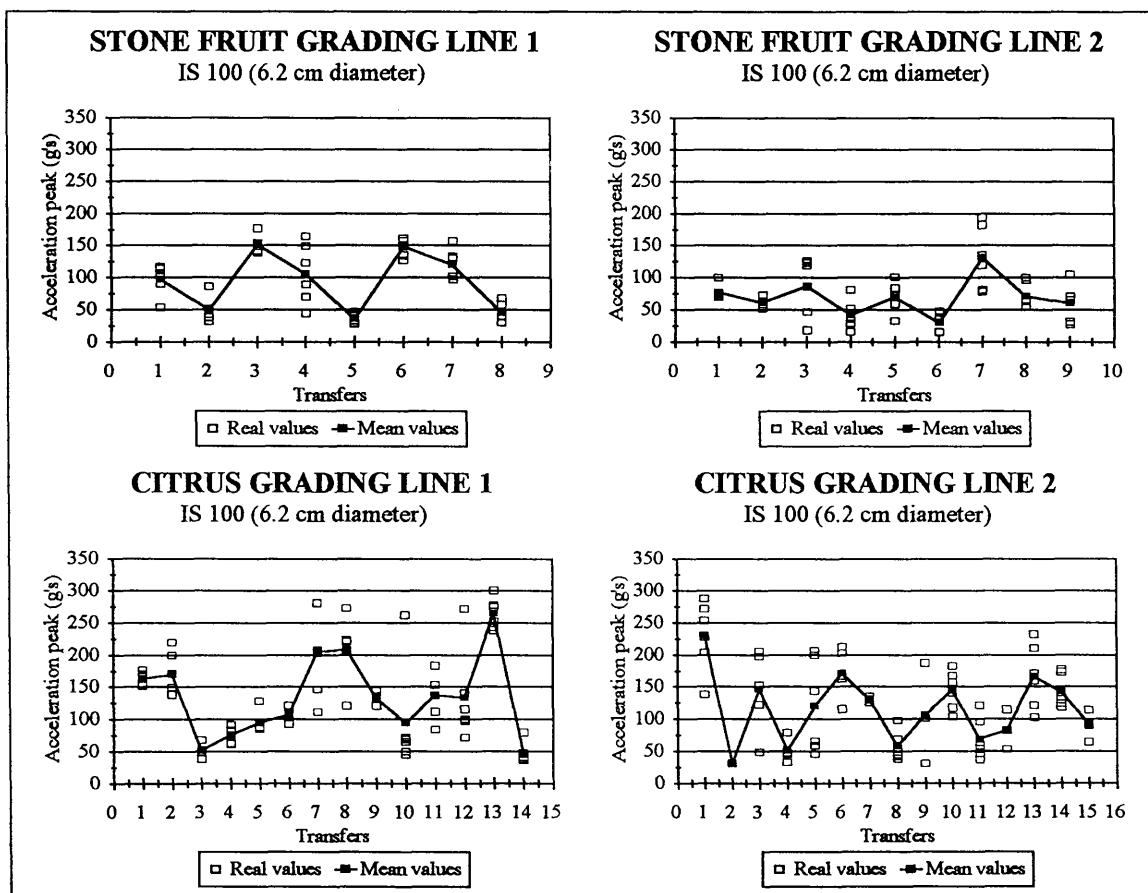


Fig. 2 Profile of acceleration peak values of tested varieties. Citrus grading lines show much higher values than stone fruit grading lines. 'Real values' are the measured data in each run and 'Mean values' are the average value of six runs.

There have been also detected some impacts not corresponding to identified transfers and whose intensity lays over 50 g's. Fruits get impacted not only at the expected places (transfers), but also in other non identified points of the line.

### 3.3. Influence of the design and regulation of the elements of the line.

Through a good design and a proper regulation of transfers it is possible to decrease the number and intensity of impacts. In fig. 3 it is shown that transfer 7 (transfer from a rollers elevator to sizer cups, photo 1) is effective as deceleration element for a big fruit (8.8 cm  $\varnothing$  IS) but not for a small one (6.2 cm  $\varnothing$  IS); the corresponding 'acceleration peak' mean values for both spheres are 44 g's and 130 g's respectively. The cushioning device is effective for the big sphere because it wraps it all around. However the distance between this element and the opposite supporting element is too large and lets the 6.2 cm sphere go through them, without wrapping it and decreasing its speed. In the graphics placed in the right of figure 3, 'acceleration peak' vs 'velocity change', it is clearly seen that the big sphere impacts against a soft element in transfer 7, whereas the small one impacts against a hard surface.

Photo 1.

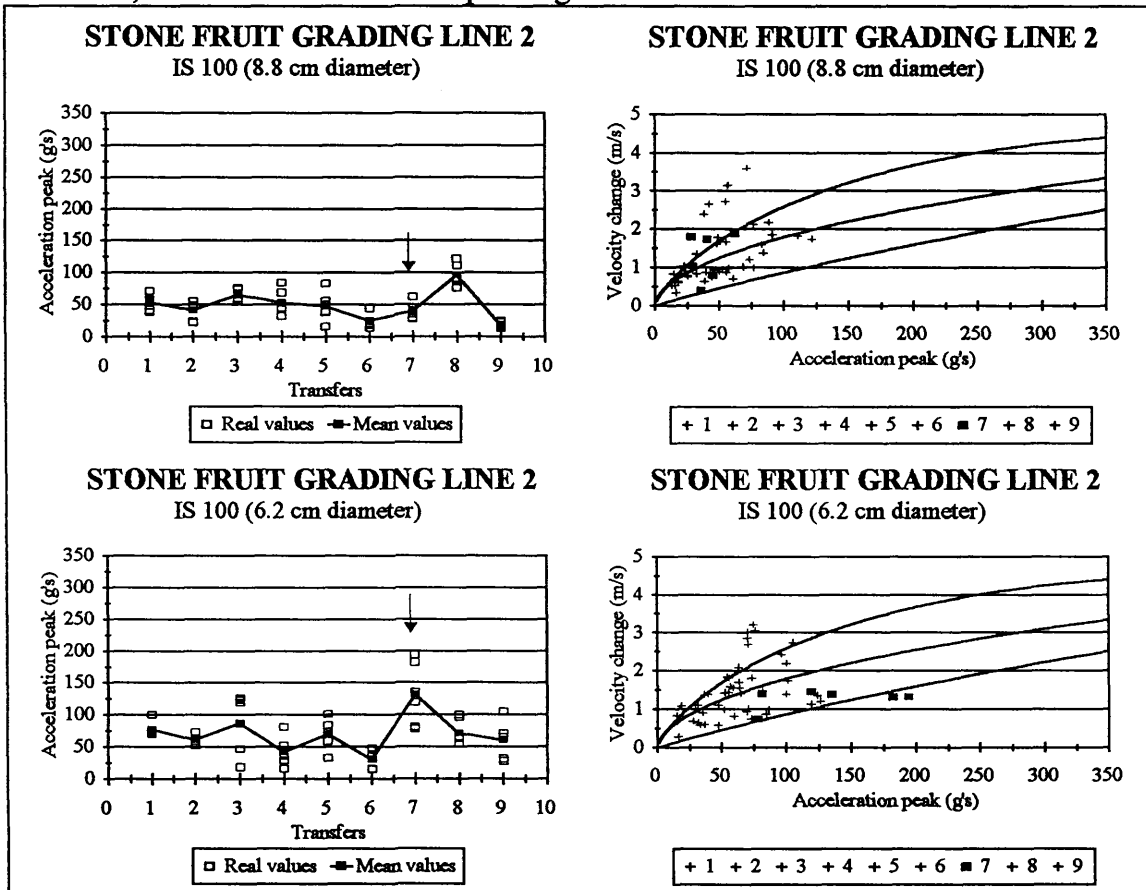


Fig. 3. Comparison of the effectiveness of transfer 7. It decelerates big fruits properly but makes no effect on smaller fruits, letting it go through it at high speed.

The design of the elements is also of capital importance. Dumping is one of the more dangerous transfers in almost every line (see transfer 1 in fig. 2). Through an optimal design of this element, high intensity impacts can be avoided (see transfer 1 in fig. 4 and photos 2 & 3). The data shown in fig. 4 correspond to the dumper of photo 2. This is an example of a good design. The 8.8 cm Ø IS did not register any impact at this point; the 6.2 cm Ø IS registered in one of the run a maximum acceleration peak of 32.9 g's. Photo 3 is an example of a bad design. This kind of dumper is the most usual model. The acceleration peak mean values for this kind of dumper vary between 53 and 157 g's for the big IS and between 77 and 231 g's for the small IS.



Photo 2. Good dumper

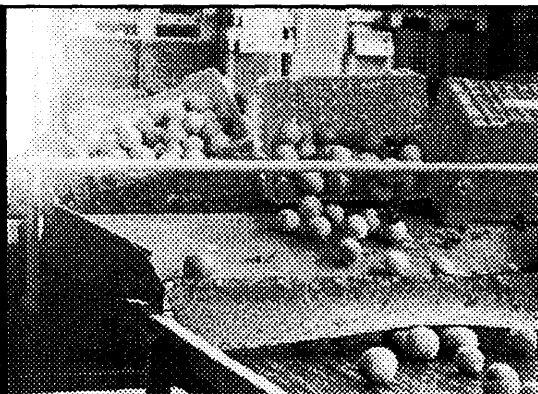


Photo 3. Bad dumper

The speed of the elements (conveyors, rollers, sizer cups, etc) plays also an important role in impact intensity and, subsequently, in bruises appearance. Low speeds and, over all, low speed differences between consecutive elements reduce substantially impacts incidence (figs. 4 y 5). Although the speed of the elements is not the only influence factor, first elements of line Stone 3 present low and similar speeds; consequently both IS registered low acceleration peak values (fig. 4): the big IS did not register any impact in the three first transfers, while the 6.2 cm Ø IS registered 28.04, 13.9 and 31.2 g's as acceleration peak mean values respectively.

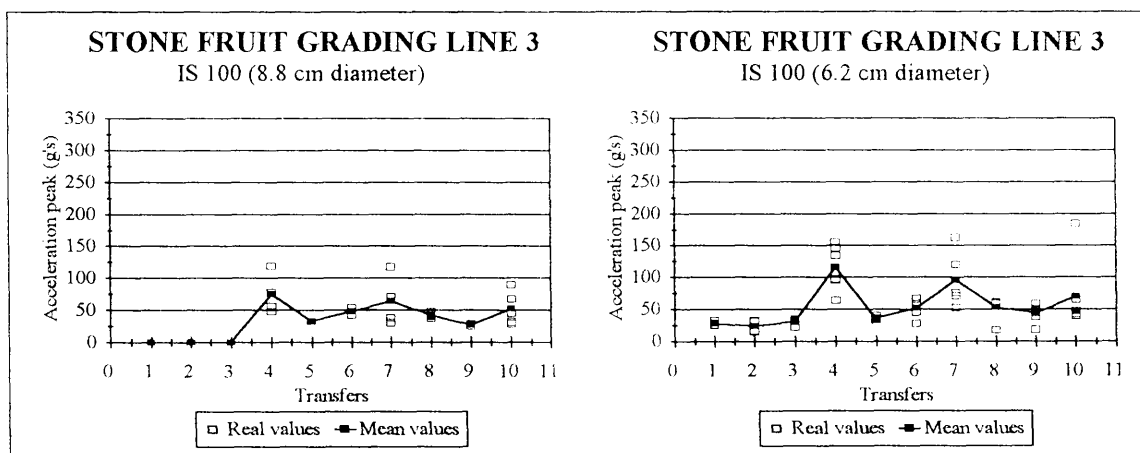


Fig. 4. Grading line of a stone fruit packing house. Low dumping impact intensities.

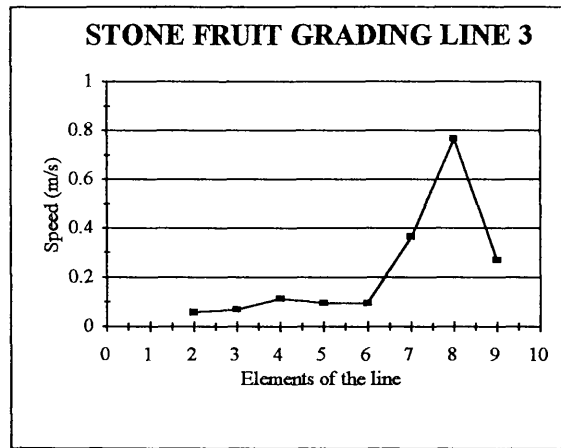


Fig. 5. Speed of the elements of stone fruit grading line 3

### 3.4. Interaction fruit-packing line

All results included under this epigraph must be understood considering that along the handling process, one of the first operations is the 'picking' phase, in which damaged fruits are manually eliminated from the line. That would mean that bruises found in the fruits of the post-handling sample are only a consequence of the mechanical processing itself.

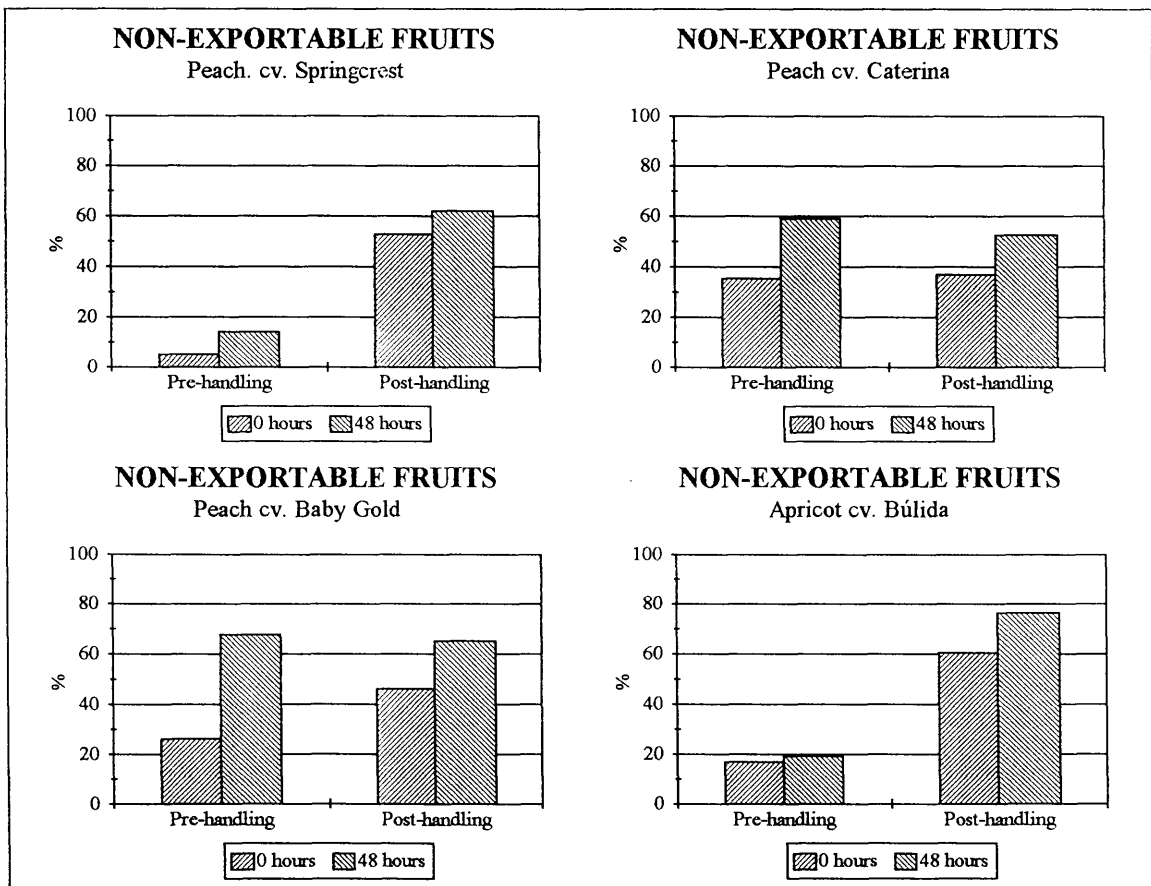


Fig. 6. Percentages of 'non-exportable' fruits ( $\approx$  fruits out of Extra or Class I categories, according to UE Standards) before and after handling.

In all cases more than 50 % of fruits belonging to the post-handling sample showed some kind of damage. Considering only the percentages of out of Extra and Class I fruits, than mean the non-exportable ones, they vary from 37% of *Caterina* peaches up to 61% damaged fruit of *Búlida* apricots. After 48 hours storage, these percentages varied between 53% (*Caterina* peach) and 76% (*Búlida* apricot).

Fig. 6 shows that bruises do evolve after 3 48 hours storage at room temperature ( $\approx 20^{\circ}\text{C}$ ) in every tested variety, increasing the percentage of out of Extra and Class I fruits, according to UE Standards.

#### 4. Conclusions

1. Although both IS are supposed to measure the same values for identical impact conditions, they register similar ranges for soft materials but not for hard materials.
2. Most transfers in the tested lines must be revised. They include high impact probabilities, being these impacts highly dangerous because of their intensity.
3. Further tests must determine proper regulations of each transfer and for each product in terms of distance between consecutive elements, speed of the elements, etc.
4. More than 50% of mechanically handled fruits show some kind of damage. These bruises evolve significantly after 48 hours at room temperature. This is a consequence of the bad state of the lines.

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